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(54) **BOND ASSEMBLY JIG AND METHOD**

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B29D 99/00	(2010.01)
B29C 70/54	(2006.01)
B29C 33/30	(2006.01)

(52) **U.S. Cl.**

CPC ***B29C 70/44*** (2013.01); ***B25B 11/02*** (2013.01); ***B29D 99/0021*** (2013.01); ***B29D 99/0025*** (2013.01); *B29C 33/30* (2013.01); *B29C 33/306* (2013.01); *B29C 70/54* (2013.01); *Y10T 156/10* (2015.01)

(58) **Field of Classification Search**

CPC B25B 11/02; B29C 70/44; B29C 70/54
USPC 156/381, 382; 269/10, 291, 297, 303, 269/315, 316, 317, 318, 319, 320; 425/389, 425/405.1

See application file for complete search history.

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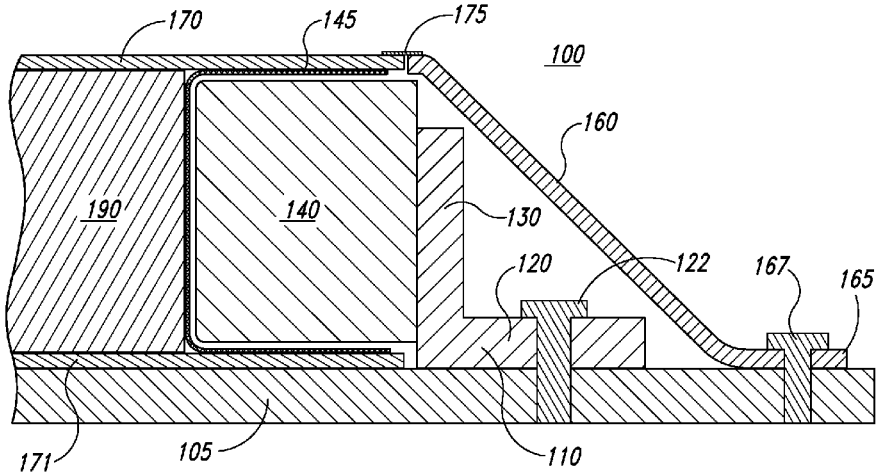
(57) **ABSTRACT**

The present disclosure provides an apparatus and method for forming a composite structure. The apparatus comprises a bond assembly jig having a support plate, an anchor member attached to the support plate, and a block member connected to the anchor member such that the block member is permitted to move in a vertical direction. The bond assembly jig can be arranged within an autoclave and may further comprise a shroud that is arranged to shield the anchor member and the block member from the pressures exerted within the autoclave. The method is accomplished by assembling the anchor member and block member on the support plate, arranging the composite materials, placing a caul component over the composite materials and a shroud over the anchor member and block member, and applying heat and pressure to the bond assembly jig to cure the composite materials.

18 Claims, 5 Drawing Sheets



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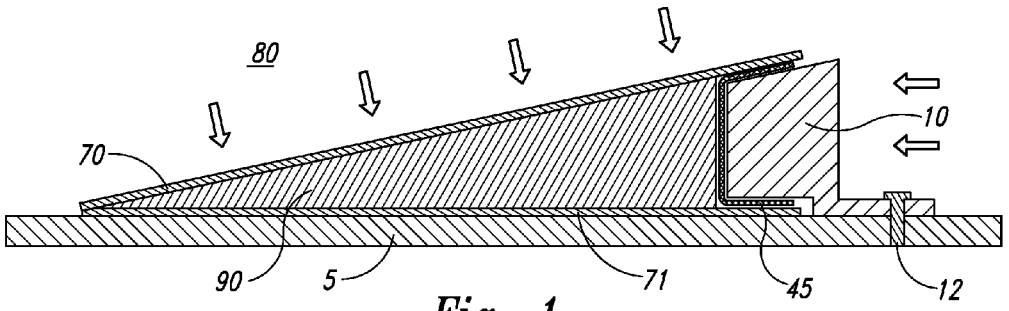

Fig. 1
(Prior Art)

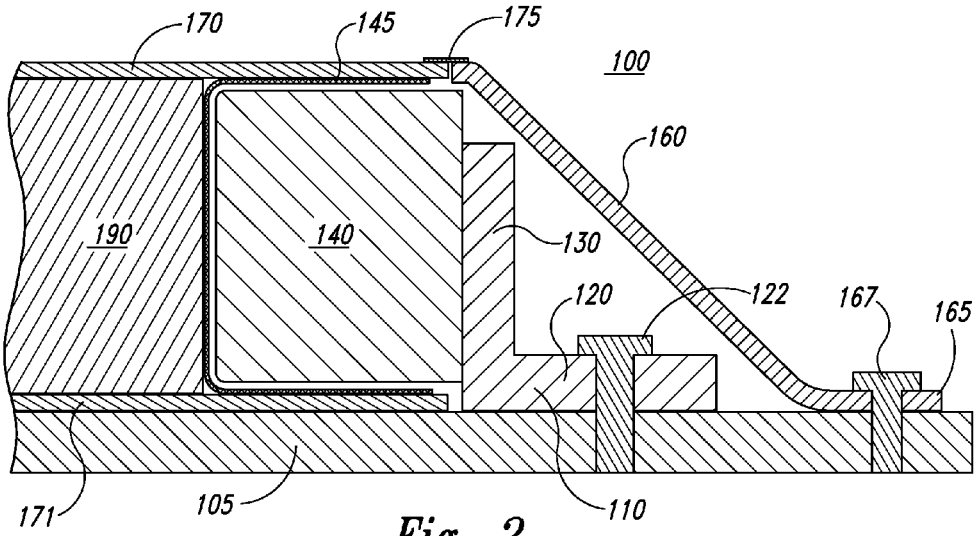

Fig. 2

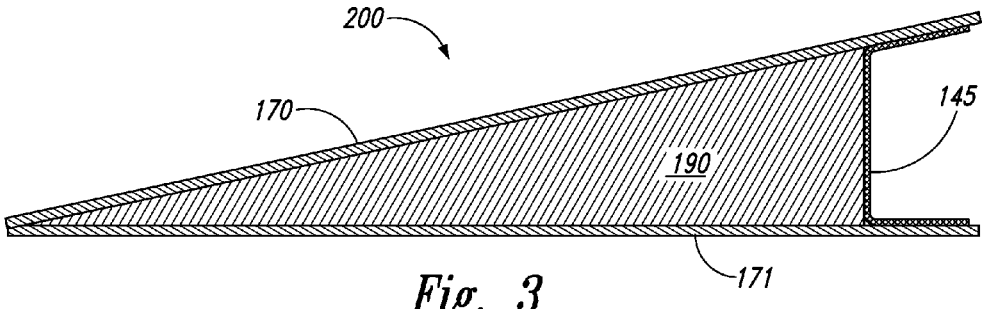

Fig. 3

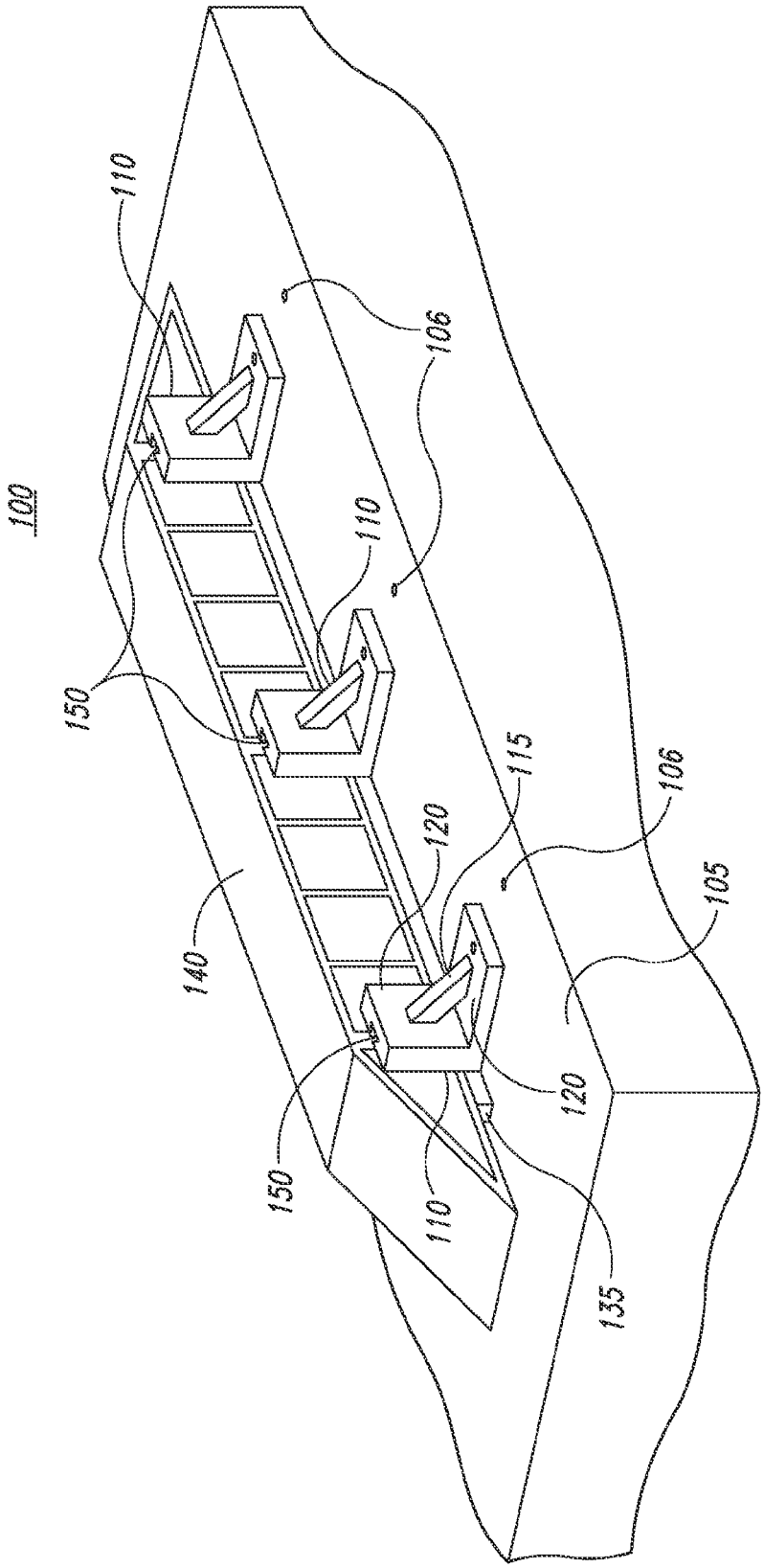

Fig. 4

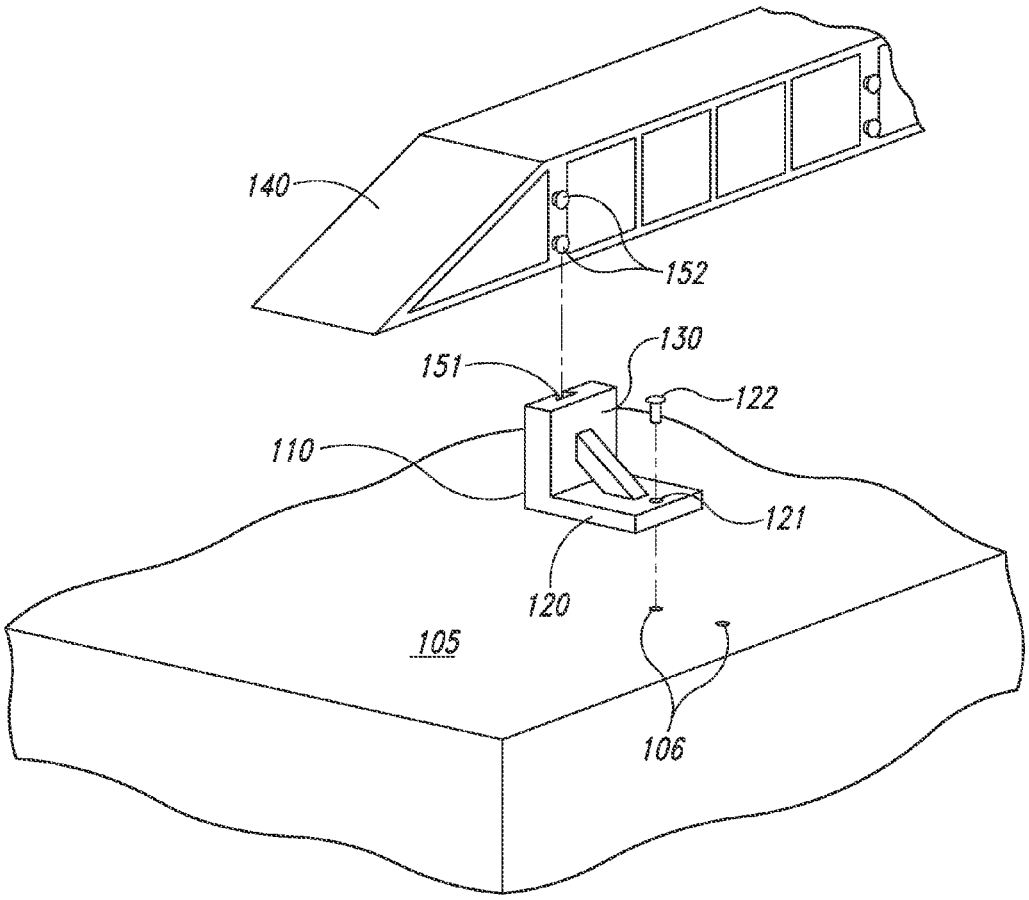

Fig. 5

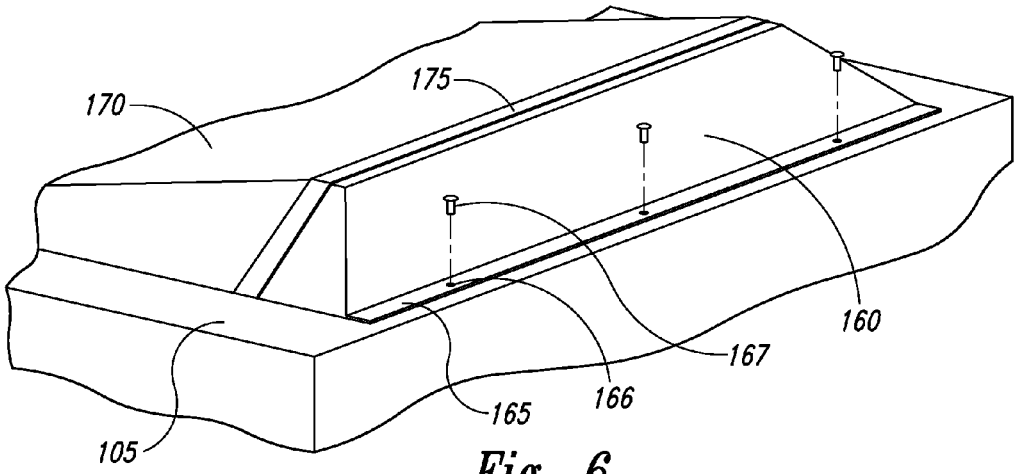

Fig. 6

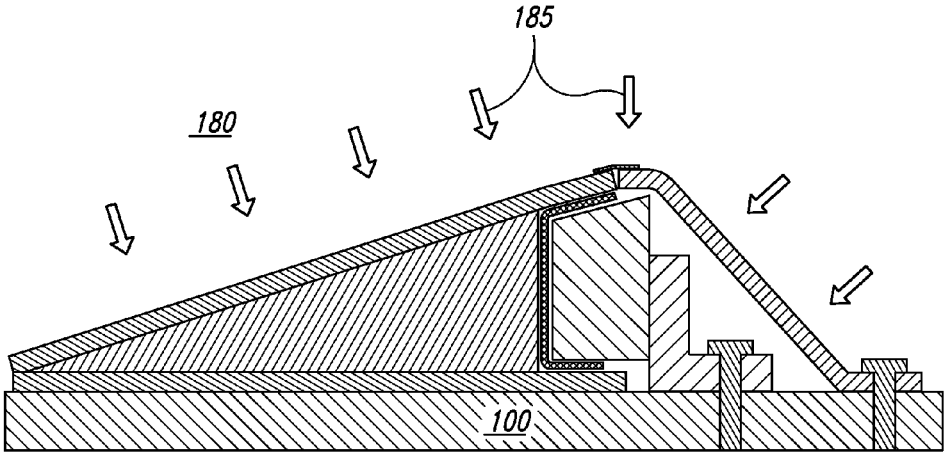

Fig. 7

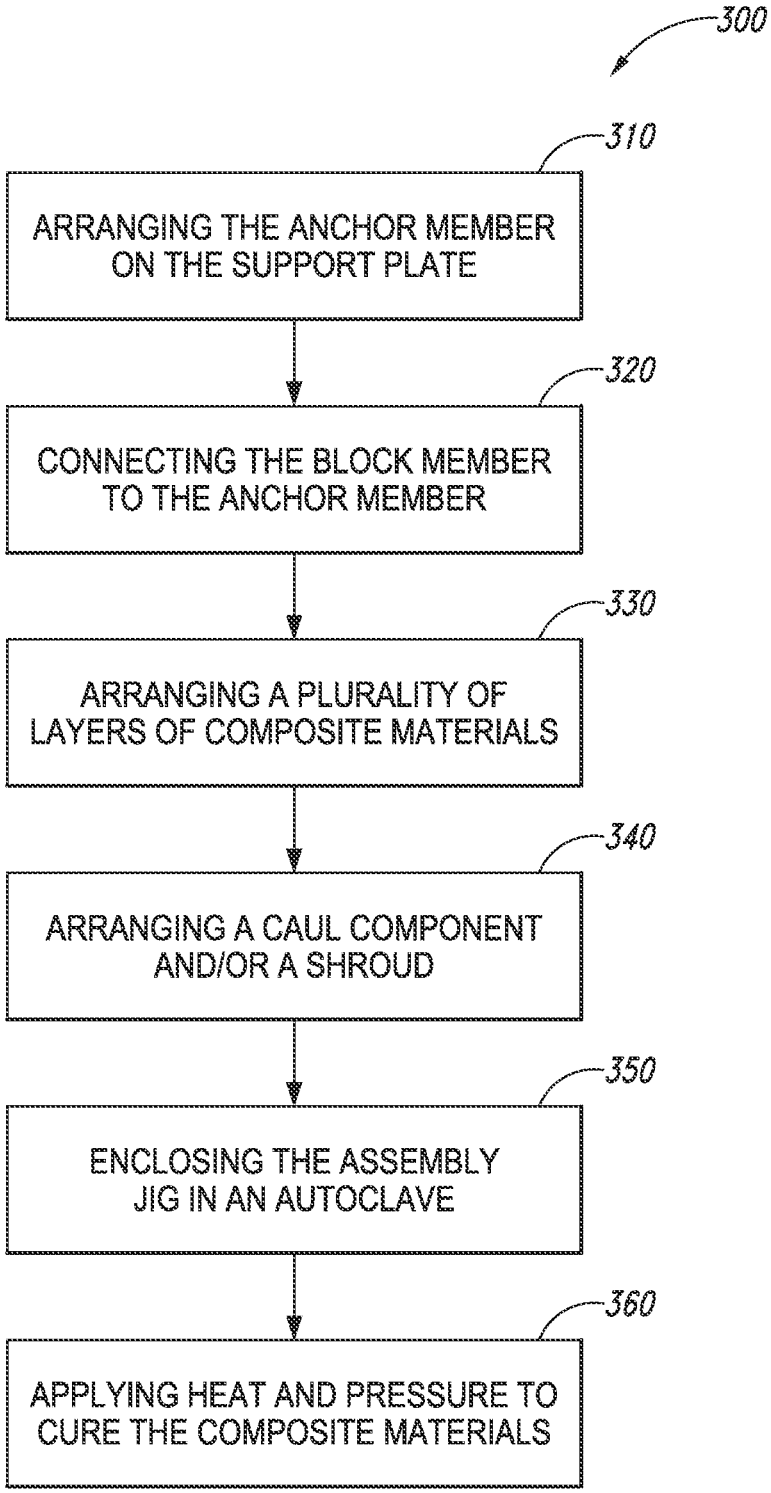
300
310
ARRANGING THE ANCHOR MEMBER ON THE SUPPORT PLATE
320
CONNECTING THE BLOCK MEMBER TO THE ANCHOR MEMBER
330
ARRANGING A PLURALITY OF LAYERS OF COMPOSITE MATERIALS
340
ARRANGING A CAUL COMPONENT AND/OR A SHROUD
350
ENCLOSING THE ASSEMBLY JIG IN AN AUTOCLAVE
360
APPLYING HEAT AND PRESSURE TO CURE THE COMPOSITE MATERIALS

Fig. 8

BOND ASSEMBLY JIG AND METHOD

FIELD

The present disclosure relates to an apparatus and method for forming a composite structure. In particular, the present disclosure is directed to an improved apparatus and method for forming an airfoil or other composite structure using a bond assembly jig and wherein the composite structure is cured in an autoclave.

BACKGROUND

Modern structures are increasingly manufactured using "composite" materials, where reinforcing materials, such as fibers, are embedded in a polymer matrix, such as a thermoset resin. Composite materials are particularly important where an important feature of the structure is the ratio of strength to weight. Aircraft components are a primary example of structures where the strength to weight ratio is a primary consideration.

One process that is commonly used to form structures from composite materials is a lay up process. In the lay up process, the reinforcing materials layers of reinforcing material are laid in a mold, either by hand or by machine. The polymer matrix is then introduced into the mold, filling the voids between the reinforcing materials. The reinforcing materials may be pre-impregnated with resin prior to placement in the mold. The materials are then cured, often by using an autoclave. Alternatively, the materials can be partially cured and then placed in a mold or on a mandrel for forming into a desired shape.

More complex composite structures are commonly built with discrete components. For example, referring to FIG. **1**, aircraft structures are often designed with a core component **90**, which may comprise a composite material or stiffening support such as a honeycomb structure, and a spar **45**, arranged between two skin components **70**, **71**. In this example, the aircraft structure is formed by placing a partially cured or uncured first skin component **71** in a bond assembly jig, which has a support plate **5** having the desired shape for one surface of the aircraft structure. Additional layers of core component **90** are added, followed by a second cured or uncured skin component **70**. A caul component may then be placed over the second skin component, having features that conforms the second skin component into a desired shape. At one end of the structure, the bond assembly jig may comprise a nose block **10** which holds the cured spar **45** in relation to the core component **90** and skin components **70**, **71**. The bond assembly jig or tool is then typically enclosed in an autoclave **80**, which exerts heat and pressure, (represented by arrows in FIG. **1**), onto the assembly in order to cure the composite materials.

When using a bond assembly jig or tool configured with a block member, a common problem occurs in which the pins **12** holding the block member tend to bind due to the lateral force exerted by the autoclave on the block member. Not only does this problem create difficulty for disassembling and reassembling the bond assembly jig. Further, the one-piece block member **10** is rigid, often leaving the adjacent spar **45** and first skin component **71** with excessive porosity or voids.

Accordingly, there is a need for an improved bond assembly jig and method which will prevent the block member pins or fasteners from binding and which will further allow the block member to float in at least one direction.

SUMMARY

The present disclosure addresses the needs in the art by disclosing a bond assembly jig and method for using such to form a composite structure. For example, one aspect of the present disclosure provides an assembly jig for forming a composite structure. The assembly jig comprises a support plate, an anchor member removably attached to the support plate, and a block member that is attached to the anchor section such that the block member may move in a vertical direction independent of the anchor member. The block member may be attached to the anchor member, for example, by using a t-slot. Other embodiments of the assembly jig further comprise a shroud, which extends above the anchor member, and a caul component, which is placed upon the composite materials. The assembly jig may be arranged in an autoclave.

Another aspect of the present disclosure provides an apparatus for assembling and curing a structure formed from composite materials, comprising a support plate, an anchor member, and a block member, as described above, and further comprising a shroud that extends from the support plate to cover at least a portion of the anchor member. In some embodiments, the shroud extends above the anchor member to meet the second skin component or a caul component. Alternatively, the caul component and the shroud may be formed as a unitary piece.

Yet another aspect of the present disclosure provides a method of manufacturing a composite part on an assembly jig/tool, the method comprising the steps of arranging the anchor member on the support plate, arranging the composite materials on the support plate, and connecting the block member to the anchor member. The method further comprises arranging a skin component or a caul component on the composite materials and placing a shroud over the anchor member. The assembly jig is then placed in an autoclave to cure the composite materials.

Other systems, methods, features, and advantages of the present disclosure will be or become apparent to one with skill in the art upon examination of the following drawings and detailed description. The features, functions and advantages that have been discussed can be achieved independently in various embodiments of the present invention or may be combined in yet other embodiments further details of which can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Many aspects of the invention can be better understood with reference to the following drawings. The components in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the present invention. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

FIG. **1** is a sectioned side view of a bond assembly jig according to the prior art;

FIG. **2** is a sectioned side view of a bond assembly jig in accordance with an embodiment of the present disclosure;

FIG. **3** is a sectioned side view of a composite structure formed in accordance with another embodiment of the present disclosure;

FIG. **4** is an illustration of a partially constructed bond assembly jig in accordance with another embodiment of the present disclosure;

FIG. **5** is a an exploded view of some of the components shown in FIG. **4**;

FIG. **6** is an illustration of a fully-assembled bond assembly jig in accordance with one embodiment of the present disclosure;

FIG. **7** is a sectioned side view of a bond assembly jig arranged inside of an autoclave in accordance with one embodiment of the present disclosure; and

FIG. **8** is a flowchart depicting a method for using a bond assembly jig in accordance with one embodiment of the present disclosure.

DETAILED DESCRIPTION

In the following description, reference is made to the accompanying drawings, which form a part hereof, and in which is shown, by way of illustration, various embodiments of the present disclosure. For example, while the discussion below focuses to some extent on the example of an airfoil constructed for use as part of an aircraft, the disclosure and its various embodiments are not limited to such use. It is understood that other embodiments may be utilized and changes may be made without departing from the scope of the present invention.

FIG. **2** illustrates an embodiment of a bond assembly jig **100** in accordance with the present disclosure, comprising a support plate or tool base **105**, an anchor member **110**, a nose block member (or spar mandrel) **140**, and a shroud **160**. The bond assembly jig **100** further comprises skin components **170**, **171** and a spar **145** surrounding the core component **190**. The anchor member **110** comprises a base section **120** and a protruding section **130**. The base section **120** abuts the support plate **105** and is held in place by anchor fasteners **120**. The shroud further comprises a flange **165**, by which the shroud is held against the support plate **105** by shroud fasteners **167**. A seal **175** may be placed at the top of the shroud **160** where it meets the second skin component **170**. Alternatively, the bond assembly jig may include caul components (not shown), wherein the shroud may be brought to meet the upper caul component.

FIG. **3** illustrates another embodiment of the present disclosure, wherein a composite structure **200** is formed using an assembly jig **100**. The composite structure **200** of the illustrated embodiment comprises a sandwich structure having a core component **190**, formed of a first material, arranged between two skin components **170**, **171** that comprise a composite material.

FIGS. **4-6** illustrate additional features of a bond assembly jig in accordance with another embodiment of the present disclosure, wherein the support plate **105** comprises a plurality of holes **106** for receiving the anchor fasteners **120** and shroud fasteners **167** through anchor holes **121** and flange holes **166**, respectively. As shown in FIG. **4**, the bond assembly jig **100** may employ a spacer **135** for positioning the block member **140**. The block member **140** is connected to the anchor members **110** via a block connector **150**. Referring to FIG. **5**, the block connector **150** may comprise a female connector **151** and a male connector **152**.

Bond assembly jig **100** is constructed with a support plate **105** on which the composite materials are arranged. The support plate **105** is configured having a generic shape and to directly support the skin component **171**, which may be supplemented with a lower caul component (not shown). The lower caul component can be configured in a specific shape to conform the composite materials into a specific composite structure **200**. See FIG. **3**. The lower caul component can also be constructed of a material and finished surface that will allow the cured composite structure **200** to be easily removed from the bond assembly jig **100**. In other embodiments, the support plate **105** may be configured to have a specific shape that conforms the adjacent composite materials into the desired composite structure **200**, wherein the lower skin panel **171** is laid up or placed directly onto the base plate **105**. Alternatively, the support plate **105** may be used for a generically shaped structure, wherein a lower caul component (not shown) is provided for other, more specific shapes.

The support plate **105** of the bond assembly jig **100** further comprises a plurality of holes **106** that are arranged to correspond to the flange holes **166** of the shroud **160** and the anchor holes **121** of the anchor members **110**. Additional holes **106** may be included in the support plate **105**, to allow multiple configurations of anchor members **110** and the shroud **160**.

The upper skin component **170** provides an outer barrier of the bond assembly jig and helps determine the shape of the finished composite structure **200**. The upper skin component **170**, as well as the lower skin component **171**, may be constructed according to any method known in the art. Alternatively, the upper skin component **170** may be supplemented with an upper caul component (not shown). In particular, the upper caul component may comprise a semi-rigid structure, which allows the upper caul component to determine the shape of the composite structure **200** while also transferring the pressure exerted by the autoclave to the composite materials within during the curing process.

The composite structure **200**, which is a product of the apparatus of the present disclosure, may be a finished structure or a rough structure requiring additional shaping via sanding or other methods. The composite structure **200** may also be designed for combination with other composite structures or other components in order to achieve the final structure. Numerous types of composite materials may be used in the formation of the skin components **170**, **171** or the core component **190**. Alternatively, the core component **190** may be formed of another material or hollow structure. The skin components **170** and **171** and the core component **190** may be fully or partially cured prior to assembly. Also, the composite materials may be prepared in the first instance in the bond assembly jig **100**.

In addition to the skin components **170**, **171** and the support plate **105**, the shape of the composite structure **200** is also determined by the block member **140**. The block member **140** is configured to provide a specific shape at one or more sides of the composite structure **200**, allowing the composite structure to be combined with other structures or components to achieve the desired final shape and other attributes. The shape of the block member in the illustrated embodiments approximates a trapezoid in one dimension. Other shapes are also advantageous and are within the scope of this disclosure, as will be apparent to one having skill in the art. In some embodiments, the shape of the block member **140** corresponds to the shape of the spar **145**, which is often provided as cured composite material component. A spacer **135** may also be provided during the arrangement of the block member **145**. After arranging the lower skin component **171** and the spar **145**, the spacer is removed.

In some embodiments, the bond assembly jig **100** comprises one or more anchor members **110** having a base section **120** and a protruding section **130**. The base section **120** and the protruding section **130** may be arranged approximately at a right angle, or any other configuration that suits a particular application. The anchor member **110** may further comprise an anchor support **115**, which provides stability to the anchor member **110**. The base section **120** further includes at least one anchor hole **121**, which is used to attach the anchor member **110** to the support plate **105** using, for example, anchor fastener **122**. The anchor fastener **122** may comprise a threaded bolt, but may also be any other type of fastener such as a screw or a clamp, which may be used with or without anchor hole **121**.

The protruding section **130** of the anchor member **110**, extends from the support plate **105** and allows the block member **140** to be attached to the bond assembly jig **110** via block connector **150**. In some embodiments, the block connector **150** forms an attachment between the block member **140** and the anchor member **110** such that the block member is allowed to travel in a vertical direction, such as necessary, for example, where changes in temperature and pressure cause the materials to expand or contract. This may be accomplished, for example, using a female connector **151** on the anchor member **110** and a male connector **152** on the block member, wherein the female connector **151** comprises a track or other device that constrains the motion of the block member **140** in only two dimensions. As will be understood by one having ordinary skill in the art, the female connector **151** and the male connector **152** may be located on either the anchor member **110** or the block member **140**, so long as there is a corresponding connection on the other piece.

Referring again to FIG. **5**, one example of a block connector **150** that allows vertical displacement of the block member **140** is a t-slot connector, wherein the female connector **151** comprises a track having a specific shape in a longitudinal direction. The corresponding male connector **152** may comprise a pin (as shown) or an inverse of the track, wherein the male connector **152** has a shape that corresponds to the shape of the female connector **151**, allowing the block member **140** to interface with the anchor member **110** as described above.

The embodiments illustrated in FIGS. **2** and **6** further comprise a shroud. Turning to FIG. **7**, the shroud shields the anchor members **110** and the block member **140** from the heat and pressure, (represented by arrows **185**), delivered by the autoclave **180**. In this manner, the shroud **160** reduces the likelihood that either the block connector **150** or the anchor fasteners **122** will deform and/or bind. In some embodiments, the shroud **160** comprises a flange **165**, which provides a surface that can be placed against the support plate **105**. The flange **160** may further include flange holes **166** for attaching the shroud **160** to the support plate **105**. As with the anchor fasteners **122** above, the flange fasteners may comprise any sort of appropriate fastener for use with or without the flange **165** or flange holes **166**. The shroud **160**, which may comprise any appropriate shape for a particular application, extends over at least the base section **120** of the anchor members **110**. In some embodiments, the shroud **160** extends above the anchor members **110** and the block member **140**, meeting the upper skin component **170**, or alternatively, an upper caul component (not shown). A seal **175** may be provided to connect the shroud **160** to the skin component **170** or the block member **140**, thereby increasing the rate of heat transfer. The seal **175** may be in the form of a tape, an adhesive, a rigid member, or other device that is available to one having skill in the art.

In operation, the features of the apparatus described above may be used to reduce the risk of a defect in the composite structure and increase the longevity of the elements of the apparatus. FIG. **8** illustrates one embodiment of a method for constructing a composite structure **300** using the above-described apparatus, wherein a first step comprises arranging the anchor member **110** on the support plate **105** (step **310**). The method **300** further comprises a step arranging the block member by connecting the block member **140** to the anchor member **110** (step **320**). As described above, this may be done using a block connector **150** that allows the block member **140** to travel in a vertical direction. The block member **140** may also be arranged using a spacer **135** to elevate the block member while the lower skin component **171** and spar **145** are arranged.

The method **300** also comprises arranging a plurality of layers of composite materials (step **330**) to be formed into the composite structure **200**. Depending on the application, this step may be performed prior to the step of arranging the block member **140** (step **320**). Also, this step may comprise arranging a caul component on the composite materials as described above. The method **300** further includes arranging a shroud over the anchor members **110** and block member **140** (step **340**). Finally, the method comprises the steps of enclosing the assembly jig in an autoclave (step **350**) and applying heat and pressure to cure the composite materials (step **360**).

It should be emphasized that the above-described embodiments of the present apparatus and process are merely possible examples of implementations and merely set forth for a clear understanding of the principles of the disclosure. Many different embodiments of the disclosure described herein may be designed and/or fabricated without departing from the spirit and scope of the disclosure. All these and other such modifications and variations are intended to be included herein within the scope of this disclosure and protected by the following claims. Therefore the scope of the disclosure is not intended to be limited except as indicated in the appended claims.

What is claimed is:

1. An apparatus for assembling and curing a structure formed from composite materials, comprising:

a support plate having a support surface;

an anchor member having a base section that is removably fastened to said support surface, and a protruding section that extends from said base section, the protruding section having a first side and a second side;

a block member that is attached to the first side of the protruding section of the anchor member in a manner that allows the block member to travel in a direction that is substantially perpendicular to the support surface; and

a shroud, removably fastened to the support surface, extending from the support plate and positioned to cover at least a portion of the anchor member without covering the structure of composite materials positioned upon the apparatus.

2. The apparatus of claim **1**, wherein the block member is attached to the protruding section using a t-slot.

3. The apparatus of claim **1**, wherein the base section of the anchor member and the protruding section of the anchor member are substantially perpendicular.

4. The apparatus of claim **1**, further comprising a seal arranged at a top of the shroud, configured to extend between the top of the shroud and the structure of composite materials positioned upon the apparatus.

5. An apparatus for assembling and curing a structure formed from composite materials, comprising:

a support plate having a support surface on which the composite materials may be placed;

an anchor member having a base section that is removably fastened to said support plate, and a protruding section that extends from said base section, the protruding section having a first side and a second side;

a block member attached to the first side of the protruding section of the anchor member; and

a shroud, removably fastened to the support plate and extending from the support plate such that said shroud is positioned to cover at least a portion of the anchor member without covering the composite materials.

6. The apparatus of claim **5**, wherein the shroud is arranged to completely enclose the base section and the second side of the protruding section of the anchor member.

7. The apparatus of claim 5, wherein the anchor member and the shroud are fastened to the support plate using a plurality of bolts that extend through a plurality of holes in the support plate.

8. The apparatus of claim 5, further comprising a seal arranged at a top of the shroud, configured to extend between the top of the shroud and the structure of composite materials.

9. The apparatus of claim 5, wherein the support plate is adapted to support composite materials comprising a first skin component, a core component, and a second skin component that is at least partially cured.

10. The apparatus of claim 9, wherein the shroud extends to meet the second skin component.

11. The apparatus of claim 5, wherein the support plate is arranged in an autoclave.

12. The apparatus of claim 5, wherein:

the protruding section of the anchor member is oriented at a non-zero angle with respect to the base section; and

the block member is removably attached to the first side of the protruding section of the anchor member.

13. An apparatus for assembling and curing a structure formed from composite materials, comprising:

a support plate having a support surface on which the composite materials may be placed;

an anchor member having a base section that is removably fastened to said support plate, and a protruding section that extends from and is oriented generally at a right angle with respect to said base section, the protruding section having a first side and a second side;

a block member that is slidably attached to the first side of the protruding section of the anchor member in a manner that allows the block member to travel in a direction that is substantially perpendicular to the support surface; and

a shroud, removably fastened to and extending from the support plate, positioned to cover at least a portion of the anchor member without covering the composite materials.

14. The apparatus of claim 13, wherein the shroud is arranged to completely enclose the base section and the second side of the protruding section of the anchor member.

15. The apparatus of claim 13, wherein the anchor member and the shroud are fastened to the support plate using a plurality of bolts that extend through a plurality of holes in the support plate.

16. The apparatus of claim 13, further comprising a seal, disposed at a top of the shroud, configured to extend between the top of the shroud and the composite materials.

17. The apparatus of claim 13, wherein the support plate is adapted to support composite materials including a first skin component, a core component, and a second skin component, and the shroud extends to meet the second skin component.

18. The apparatus of claim 13, wherein the support plate is arranged in an autoclave.

* * * * *